Behavior in Music:

A Preliminary Definition and Exploration

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I remember the first time I listened to Iannis Xenakis's (1922 – 2001) music—it was *Jonchaies* (1977). Without knowing about the complexity of Xenakis's music, or the rigorous methods by which he composed the piece, I understood it to be formally coherent and the material logically transformed and developed, despite sounding like nothing I had heard before. It was a new listening experience, and I wanted to know more about how he accomplished such musical affect. This was the impetus for my investigation on behavior in music.

As Xenakis explains in *Formalized Music,* in the 18th century, basic Plutonian causality was expanded to include statistical theories in physics that described graduated chance, or indeterminism.[1] While the notion of pure chance remains undefined in The Sciences, graduated levels moving from purely deterministic to the border of indeterminism can be described using statistical theories. Music's response to this expanded causality was the emancipation of dissonance; however, it was quickly confined by strict determinism with the advent of serialism. The result is a musical surface that bears no relation to the traditional polyphonic techniques of transformation utilized in composition. Xenakis responded by exploiting these new statistical theories found in physics to generate and control continuous transformation of musical material. In doing so, he reestablished a connection between music and the expanded theory of causality. In consequence of writing music that utilizes statistical equations, he introduced the concept of behavior in music. This paper will explore Xenakis's formalized methods of composition through the lens of behavior, and will conclude by proposing future applications of the concept in composition, theory, and musicology.

For the purpose of this paper, I will define behavior as the relationship, interaction, change, or motion of anything that can be observed or theorized about using logic, science, or mathematics. Additionally, I will define behavior in music as portions of music where the constituent elements mimic the relationship, interaction, change, or motion of a non-musical entity in such a manner as to be observable and similar to a translation of the non-musical entity's behavior into musical material. Throughout the paper I will continually question whether or not the musical behavior is potentially perceived as such by listeners.

We will now take a look at two explicit examples of behavior in music. Claude Debussy's (1862-1918) *La Mer* was written between the years 1903 and 1905.[2] The piece is not programmatic in the traditional sense, but rather creates a portrait of the sea musically. At the outset of the second symphonic sketch, *Jeux de vagues* (the play of the waves), we get a sense of floating atop an undulating ocean as the waves pass beneath us. While the title of the sketch certainly does set the stage for our listening experience, the behavior of the musical material itself consistently reinforces our understanding of the piece as being the subject of waves. The rise and fall of 16th note flurries and dynamic swells in the woodwinds and harp mimic the passing of waves. The tremolos in the strings reflect the shimmering surface of the sea as the sun rises. The majority of the musical devices and transformations that Debussy employs mimic the behavior of waves, and I suggest that we understand it as such.

A more recent work that utilizes the behavior of the ocean as a method of creating a piece of music is Shane Myrbeck's (b. ?) *Tides* (2015), in his collection titled *The City Suite*: 4 Small Pieces. In Myrbeck's description of the movement, he states:

> "[...] tides can be heard entering and leaving San Francisco Bay at the seven NOAA monitoring stations closest to San Francisco's coastline. The time of high and low tide at each station is punctuated by a plucked sound. The frequency (pitch) of the sound illustrates the depth of the water at each point […, and], water temperature at three locations is represented by a low roar."[3]

The subject and techniques used in this piece have similarities to the ones used by Debussy; however, there is one significant difference: the perceived sonic surface does not create the sensation of experiencing the ocean.

We experience the numerous swells heard in *La Mer* in approximately the same time intervals that we would experience waves out on the Ocean. In Tides, however, the numerical information used to create the sonic events spans the course of one year, and is compressed into approximately three minutes of audio. This demonstrates the importance of things happening in, or close, to real time if they are to be perceived as behavior. This notion will be discussed further in a discussion about Xenakis's compositional methods.

Before delving into the specifics of Xenakis's techniques, it would behoove us to understand his motivation for creating an entirely new, formalized method of composition. His desired result is established at the beginning of his book *Formalized Music*, where Xenakis states, "art, and above all, music has a fundamental function, which is to catalyze the sublimation that it can bring about through all means of expression."[4] in subsequent readings, we find that he believes contemporaneous methods of composition inadequate to achieve this end goal. The music of antiquity through the mid-nineteenth century was strongly influenced by Pythagoras and Plato, and thus was strictly "causal and deterministic." this maintained until ideas of stochastics influenced philosophy by defining degrees of indeterminism. Music's response to this was atonality. However, as Xenakis comments, it quickly constricted itself with the "virtually absolute determinism of serial music."

Additionally, Xenakis believed that there was an inherent contradiction between the compositional method and the resultant sound, that is, traditional polyphonic methods controlling transformations of complex sound masses.[5] Xenakis's solution was to use a more general causality to control the transformation of sound masses. That more general causality was stochastics, thus reestablishing causality in music. The importance being, causality in music necessitates different comprehension than music without causality or music where the causality is imperceptible.

Imagine “natural events such as the Collision of hail or rain with hard surfaces, or the song of cicadas in the Summer field.”[6] the resultant soundscape of these natural events may be described as being “made out of thousands of isolated sounds.” The occurrence of these sounds follow “aleatory and stochastic laws.” Xenakis claims that, “if one wishes to form a large mass of point-notes, such a string pizzicati, one must know these mathematical laws, which, in any case, are no more than a tight and concise expression of chain of logical reasoning.”[7] Again, one must ask the question, is using stochastic models to generate music material perceptible by an audience? Research in music cognition and music psychology seems to suggest that it would be. This notion will be explored in a section that follows.

In formalizing his compositional methods, Xenakis breaks music down into its constituent elements and theorizes new ways of understanding these fundamentals of music and methods of organizing using stochastic principles. In sound, Xenakis draws a distinction between structures that exist in-time and outside-time.[8] Fundamental to the occurrence of a sonic event are elements such as pitch, intensity, duration, rate of change, timbre, color, and so on. These characteristics of sound constitute the most basic elements of music, which poses outside-time structures. The structure of these elements, once divorced from time, are abstract. That is, while they may be totally ordered in hierarchical arrangement, the elements themselves do not suggest any specific ordering.

Fundamental to Xenakis's understanding of time is the research of Swiss Psychologist Jean Piaget in his research titled *Le développement de la notion du temps chez l'enfant*. In this publication, Piaget describe a problem that is particularly relevant to Xenakis's compositional methods, "We are far too readily tempted to speak of intuitive ideas of time, as if time, or for that matter space, could be perceived and conceived apart from the entities or the events that fill it."[9] He continues by defining space and time, and states,

> "space suffices for the coordination of simultaneous positions, but as soon as displacements are introduced, they bring in their train distinct, and therefore successive, spatial states whose coordination is nothing other than time itself. Space is a still of time, while time is space and motion--the two taken together constitute the totality of the ordered relationships characterizing objects and their displacements."[10]

In a similar fashion, Xenakis conceived of time as resulting from the ordering of outside time structures and the motion between them.[11] But how then, can one order these outside-time structures when the motion between these structures themselves creates temporality instantaneously?

Piaget proposes that if time is the coordination of motion in the same way that space is the logic of objects, "we must expect to discover" [ ] operational time, which would describe the relationship between succession and duration in terms of operations in logic."[12]

As an example of this, Xenakis describes, "Three sonic events [that] are distinguished [temporally, and] which divide time into two sections within the events. These two sections may be compared and then expressed in multiples of a unit. Time becomes metric and the sections constitute generic elements of set *T*."[13] Set *T* may be thought of as an inside-time structure. Therefore, "a musical composition examined from the temporal point of view shows that the sonic events create durations on the axis of time [...]. This set is ordered with the aid of temporal algebra, independently of the outside-time algebra."[14]

Thus, Xenakis defines three types of algebra, one for each structure: 1) algebra outside-time, temporal algebra, and algebra in-time; issuing from the correspondences and functional relations between the elements of outside-time and in-time structures, independent of the outside time structures.[15] Behavior in music exists in this third form of algebra. It is the relationship, or more importantly the transformation, found in these outside time structures, placed in time, that transcribes behavior. Furthermore, I propose that it is in this third form of algebra that our minds understand the transformation of musical material, and thus behavior.

in a "Table (Mosaic) of Coherences"[16] Xenakis outlines and number of compositional methods that model a gradation of indeterminism to determinism as free stochastics, Markovian Theory, Game Theory, and group Theory respectively (see figure 1).

In looking at an overview of Xenakis's compositional methods, we see a vast number of complex relationships that align music with science, mathematics, philosophical thought, and that Xenakis spent a great deal of time formalizing a method of composition to create music that obeyed stochastic laws in order to utilize an expanded notion of causality. Xenakis believed that serialist music was in a crisis, and traditional methods of composition could not be used to transform sound masses effectively. If that were true, can we assume that stochastic composition would effectively transform sound masses by aligning music more closely to the indeterminism and determinism we experience in non-musical events?

Research in psychoacoustics, music psychology, and music cognition, shows that our brain, while listening to music, shares cognitive resources with a number of other, extra musical processes. This may indicate that we comprehend music in way similar to how we comprehend non-musical events. Many studies on perceptual grouping and segmentation suggest that infants as young as four and a half months old preferred regular phrase groupings in classical music.[17] Studies also found that infants prefer relatively long notes and downward pitch contours at the end of phrases and suggest that these segmentation preferences may exist because of similarities to speech and how they naturally mark the end of all auditory signals.[18] Peretz Patel notes that human working memory shares cognitive resources between processing melodic contour and prosodic memory.[19] Researcher Martin Clayton suggests that temporal expectations and entrainment are used to establish musical expectation, which is similar to the expectations experienced in speech production.[20]

Entrainment also plays a significant role in the way by which we perceive phrase, rhythm, and periodicity. A regular or periodic pulse can facilitate temporal coordination between performers and can elicit a synchronized motor response from audience members.[21] Other research suggests that music instantiates a “perception-action cycle,” where “streams of sensory information forming the basis of goal-directed actions.”[22] That is, evidence of neural stimulation and mirroring. Neural mirroring occurs when one here's an intentional action, and as a result, experiences neural activity similar to that if they were the one performing the action.

Mismatch negativity, or MMNs are observable neuron firings, that occur when one’s expectations are not met.[23] These MMNs can be used to understand how and why humans create expectations about music. Research suggests that listeners constantly understand music based on its behavior, and creates expectations about how it will behave in the future. Furthermore, MMNs can be seen in infants, which suggests that infant MMN is among the first developing cortical responses to sound.[24] This indicates that humans develop their ability to create expectation using environmental sounds. Research would be necessary, but there is a possibility that, even as adults, we still use long term memory of these abstracted environmental sounds to create musical expectation.

This research suggests that the way by which we process and understand music is similar to the ways that we process and understand speech, environmental sounds, and gestures. The music of Xenakis materializes and transforms music in a way similar to the behavior of events that we experience on a daily basis. Evidence suggests that brain development allows us to effectively listen, encode, and create expectations regarding these sound events, and consequently music that behaved similar to them, even if only on a subconscious level.

Now that we have taken a look at Xenakis's motivation for developing methods for using stochastics in composition, a general idea of his methodology, and a little about how the brain processes sound, let us take a look at specific examples of Xenakis's music. We will Begin by looking at Achorripsis, which uses freely stochastic methods of construction and mimics indeterminism.

As is described in *Formalized Music*[25], Xenakis begins by creating a vector matrix that is made up of metric time units equaling 15 seconds each on the x-axis, and 7 different timbral groups on the y-axis, which are combinations of the 21 instrumentalists in the ensemble (See figure 2). Xenakis then uses Poisson's formulae to distribute sonic units, and then two laws of continuous probability and Gaussian distribution to distribute all aspects of outside time elements in a purely indeterministic way to the distributed sonic events (See figures 3 and 4). After each element has been distributed appropriately, he translates this into traditional notation (see figure 5). As is observed in both the method of creation and the resulting sound, Xenakis created a piece of music that behaves in a manner that is as closely akin to indeterminism.

In Metastasis, Xenakis uses three-dimensional vector arrays to create large orchestral sweeps. He took this one step further and used the vectors created in Metastasis to create a design for the Philips Pavilion for the Brussels's world's fair in 1958[26] (see figure 6). Nomos Alpha uses the symmetric transformations of a cube to create a hexahedral group with permutations per the cube's symmetric orientations[27] (see figure 7).

While the complexity of Xenakis's music may rely on cognitive function and subconscious understanding of behavior, the notion of behavior in music opens the door for a new way of understanding, composing, and studying all music. At the very least, the idea of tendency tones or harmonic motion could shine in a new light while understanding them as behaving in a predictable way. Voice leading rules and counterpoint in Baroque music are already imbued with the notion of behavior—each voice maintaining a specific role. The extant idea of question and answer in the phrasing and contour of melodic lines is already on the cusp of understanding musical style as behavior. This coupled with research on the similarities between cognitive processes used to decipher speech and music could provide a very fruitful method of understanding phrasing and harmonic motion, both within and outside of tonality.

Furthermore, behavior could provide an entirely new method of understanding how we fabricate correlation between disparate elements of music. An expansion of the behavior found in Xenakis's music to more commonly observed types of behavior could also open the door for new compositions, which intentionally alter audience. Applications beyond music include, painting, sculpture, dance, and architecture. Xenakis himself, as seen in the "translation" of Metastasis into the Philips Pavilion, proved that the application of stochastic organization has a place in numerous art forms.

Xenakis was the first to explicitly use formulas that define the behavior of non-musical entities to create music, thus opening the door for an entirely new perspective on the arts; one that has the potential of expanding the way by which we see the world around us, thus, ironically, defining a new type of behavior involving the creation and study of music and all art.

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